Nuclear Power in a Competitive Market Place

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Introduction

Susumu Yoda (1995), President of Japan's Central Research Institute of Electric Power industry, in his book **"TRILEMMA: Three Major Problems Threatening World Survival"** states that "amid the explosive rate at which the world's population continues to increase. the accompanying and unavoidable increases in energy consumption, and the resulting reality of the deterioration of the environment, the human race is faced with a triad of serious problems- economic growth, consumption of energy and resources, and conservation of the environment- in other words, the world finds itself facing a formidable Trilemma." Figure 1 illustrates Mr. Yoda's structure of this triad or trilemma (1995).

In 2050 the world's population is estimated to reach 10 billion. The scale of today's economic activity will have to be five times larger in order to meet the fundamental needs and minimum requirements of that population. This will entail an enormous consumption of resources especially the food supply, energy, and water, all of which in turn will irreversibly affect the environment (Yoda, 1995). Simultaneously, the current disparity in the consumption of these resources between the developed countries of the Northern hemisphere and the developing countries of the Southern hemisphere will be further exacerbated as the South embarks on its own "Industrial Revolution" to achieve the North's standard of living. In the developing countries. the economic foundation is very weak, and even if high-tech technology is developed, it may be very difficult to introduce to those areas. The alternative is a second "Industrial Revolution" similar to that of the North's in the 1750-1850 period. This revolution which also would be fossil fuel based would significantly dwarf in magnitude that of the 1750's and could have a catastrophic impact on the world's environment. Many believe that such a revolution could ultimately destroy the earth. However, it is also imperative from the perspective of world stability that the undeveloped countries decisively narrow the standard of living gap that exists between North and South.

The intent of this paper is to illustrate one solution to the Trilemma facing Planet Earth by presenting a strategy on how to meet the needs of the burgeoning population and the industrialization and development needs of the South. That solution is the expanded use of nuclear power. Nuclear power can not only meet the global energy demand of the population growth and rising living standards of the undeveloped countries but also minimally impact the environment. However, the challenges which nuclear power is facing with electric utility deregulation and a competitive marketplace will profoundly impact the ultimate role which this technology will experience – at least in our country.

Moreover. proliferation of nuclear materials is recognized as a major concern in expanding the use of commercial nuclear power, especially to unstable developing countries that do not have a sizable industrial infrastructure. These countries potentially could pose a serious proliferation concern if they had nuclear capability.

How nuclear power is implemented into the global arena to meet the expected energy demand while maintaining a healthy environment without giving developing countries potential nuclear weapon capability is also a dilemma to be solved in conjunction with Mr. Yoda's Trilemma. Strategies addressing that dilemma have been presented elsewhere (Naughton, 1998). This paper, while illustrating that nuclear power is one solution to the Trilemma, will also consider the realities and risks that dominant nuclear power's choice from a business perspective. First, the case for nuclear power will be examined.

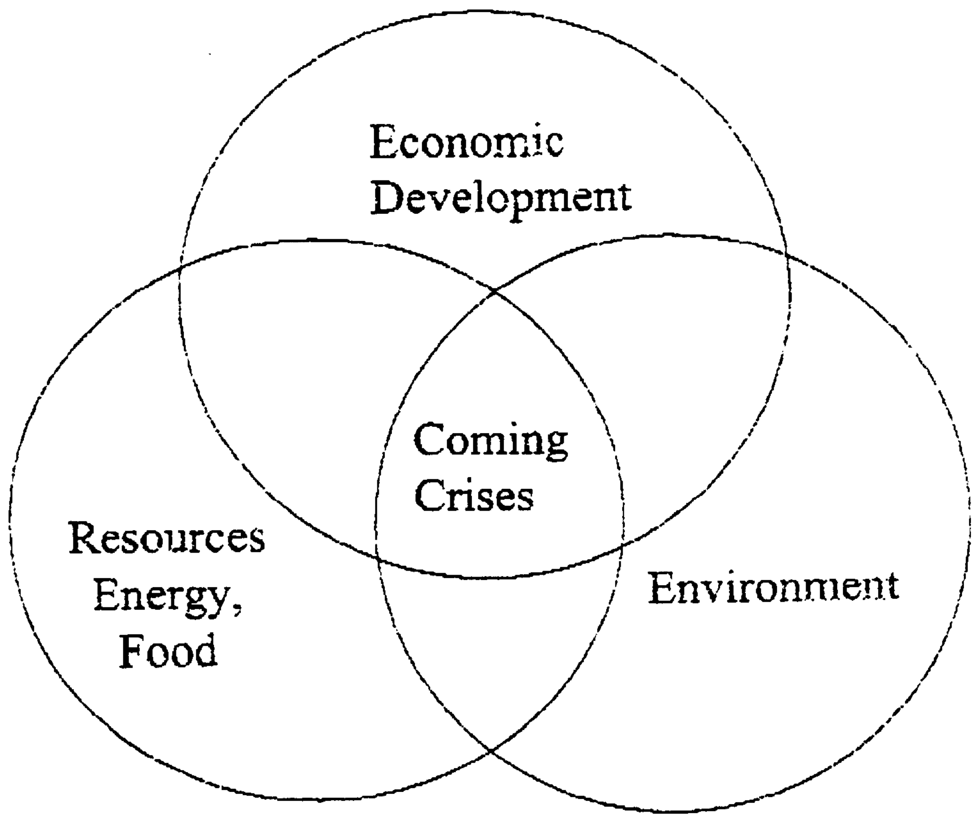
Current Global Energy Demand

Dr. Chauncey Starr, President emeritus of the Electric Power Research Institute stated in his 1993 paper on "Global Energy and Electricity Futures:" (ANS, 1995)

> "By the middle of the next century, global energy demand driven by population and economic growth, will be in the range of 2-4 times the present level, depending on the effectiveness of energy efficiency and conservation globally. Even with maximum realistic conservation the electricity component will be more than 4 times present usage. A massive expansion of non-fossil sources would be needed to slow the future annual increase in carbon dioxide to the atmosphere."

We cannot expect and should not wish the developing nations to forego the benefits of abundant energy that the industrialized world has enjoyed for many decades. As an example, consider Asia, which is home to two-thirds of the world's population. China alone adds a population the size of Canada each year and its economy is growing 2 ½ times as fast as the United States economy (NEI, 1997). Coal currently accounts for about 70% of China's electricity output. China's energy demand is now only a sixth of the global average. a tenth that of Korea. a twentieth that of Japan and a mere thirtieth that of the US. However, if it were to require the world's average, as it may within the next 15 years, it would use more than Western Europe now does. When China catches up with Japan, as it will, it will then consume three times the energy of the US (Blix, 1997).

Figure 1. The Structure of the Trilemma



Impact of Fossil Fuels on the Environment

Currently known world resources of coal are equivalent to about 200 years of consumption at present levels, although additional resources can be expected to be developed. In general, however, fossil fuels are unevenly distributed throughout the world. Additionally, their transportation costs are an obstacle to their use in many countries or in extensive regions of several large countries. As a result of the oil embargo, considerations of national energy security, to which many countries with inadequate domestic fuel resources attach high importance, are a further factor that will discourage complete reliance on fossil fuels in many regions of the world (ANS, 1995).

When health and environmental problems such as smog, particulate emissions, acid rain, and in the long term the potential greenhouse effect are taken into account, then fossil fuel use will be constrained. Today's chief concern is related to CO_2 emissions which are believed to contribute to the increase in the temperature of the world's atmosphere - global warming. After a long period of stability, CO_2 levels began to rise with the onset of the Industrial Revolution. The increase shown in Figure 2 has become progressively more rapid in this century, reflecting the ever increasing consumption of fossil fuels. In an attempt to gauge the changes ahead, a United Nations panel made a range of estimates of how carbon levels would increase in the 21st century under a "business as usual" scenario, i.e. absent any effort to limit carbon emissions. Figure 3 illustrates the United Nations Low End and Worst Case scenarios. Many scientists believe the likelihood of catastrophic climate changes will increase the closer the atmosphere approaches a doubling of the pre-industrial carbon level which is predicted to occur by the UN Worst Case scenario in 2050 (NYT, 1997).

Currently, the U.S., China, and the Russian Federation are the world's biggest emitters of CO_2 per year, accounting for about 43% of the total metric tons per year. The U.S. alone contributes 25% (WSJ, 1997). Recently, at the Kyoto Conference in Japan the represented nations of the world promulgated a goal to reduce CO_2 emissions by 7 percent below 1990 values. To even maintain CO_2 concentrations at present levels, which have increased dramatically over the last two hundred years as previously shown in Figure 2, and to avoid the damage created by the greenhouse effect, fossil fuel consumption would have to be decreased by more than half of the current levels. The impact of such a drastic step today on the global economy would be both unprecedented and incalculable, even before taking into account the additional step of meeting the goals of the Kyoto accord. Thus, an alternative non-fossil source of energy is not only needed today, but will be imperative to fuel the increasing future energy demand while maintaining a quality environment. Other than renewable energy sources, the only other non-fossil energy source available today that has the potential to meet this future demand is nuclear power.

Figure 2. Atmospheric Carbon Dioxide Over Past 250 Years

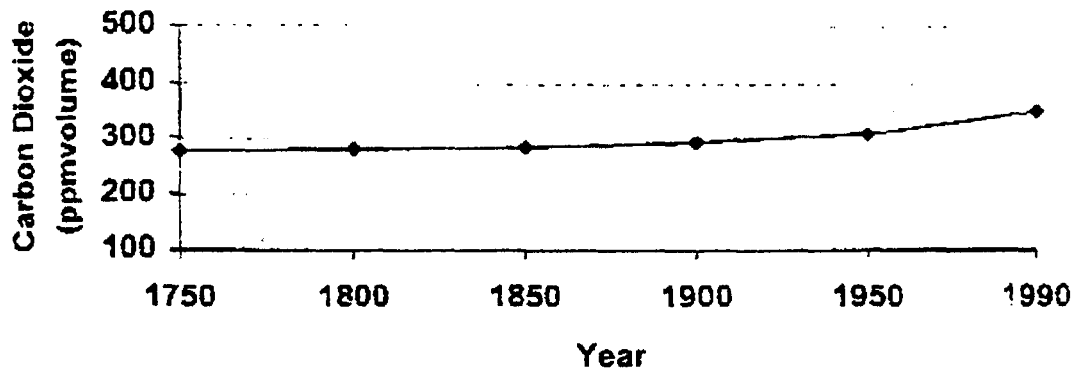
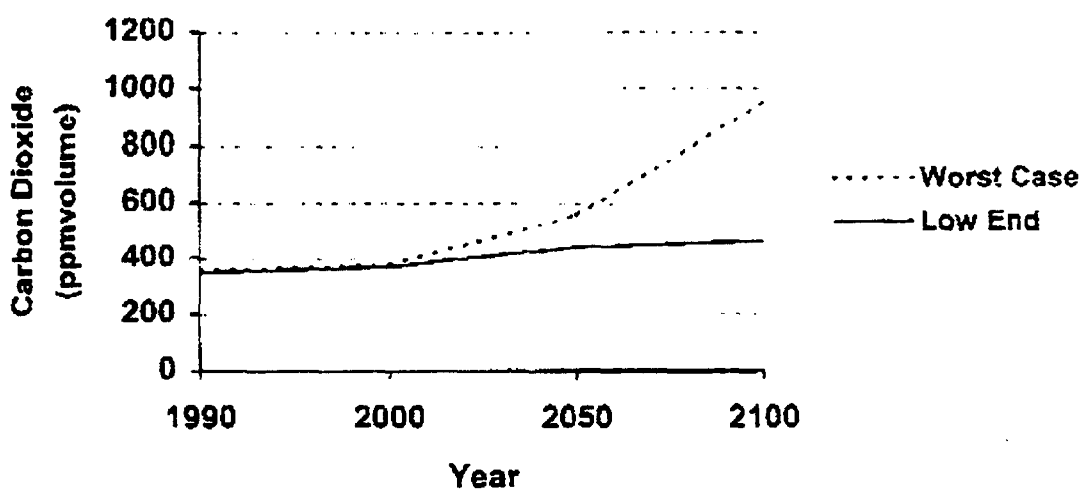


Figure 3. United Nations Predictions on Future Atmospheric Carbon Dioxide Concentrations



Renewables and Nuclear

Currently, the renewable sources now provide about 2 percent of the world's commercial energy. The bulk of that total comes from geothermal installations, new wind and solar technologies, and biomass plantations. This share could increase, but only to a limited extent even with adequate support. Additionally, the renewables have several inherent and severe handicaps that affect their economy and usefulness in a modern world. Solar rays and winds are intermittent, and until we have found effective ways of storing electricity, these sources cannot provide the electricity that we need around the clock – the baseload electricity (Blix, 1997).

In reality humankind has gone from the use of wood to coal, oil, gas, and uranium because of the higher energy concentration of these sources. This energy density has offered economy and convenience. Table 1 illustrates the meaning of energy density by comparing the energy equivalent of 1 kilogram of various materials in kilowatt-hours (kWh) of electricity (Blix, 1997).

Table 1. Energy Equivalent of 1kg of Material in kWh

Material	Kilowatt Hours Electricity
Firewood	1
Coal	3
Oil	4
Natural Uranium	50,000
Plutonium	6,000,000

To capture significant amounts of energy (electricity) from the low energy density renewables requires "harvesting" them over large areas, which is expensive. For example, to achieve the electrical generating capacity of a 1000 MWe power plant, an area of 50 to 60 km^2 would be needed to install solar cells or windmills, or an area of 3000 to 5000 km^2 to grow the needed biomass. Obviously, it will not be easy or cheap to acquire such large areas, particularly in densely populated areas where the energy will be most needed. In contrast, a nuclear reactor would only require an area of a few square kilometers (Blix, 1997). In no way should the foregoing indicate that renewables are not important in contributing to the global energy needs and the favorable impact that they will have on the environment. In the short or medium term these sources will not be capable of bringing us the huge quantities of energy that will be demanded. Only nuclear power has that capability.

The Case for Nuclear Power

Nuclear power is one of the most environmentally sound energy sources in worldwide use today. Table 2 compares CO_2 emissions in metric tons for nuclear, coal, oil, and natural gas per one million kilowatt-hours of electricity (NEI, 1997).

Table 2. CO_2 Emissions in Metric Tons per 1,000,000 Kilowatt-Hours

Energy Source	CO_2 Emissions
Nuclear	0
Coal	230
Oil	200
Natural Gas	160

A more striking and significant example can be seen from the French nuclear program. In a paper presented by Bauer and Fabre of Electricite de France at the 1989 Chicago American Power Conference, these authors showed that:

> "...from 1975 to 1988, French electricity consumption almost doubled. During the same period, the nuclear electric generation went from roughly ten percent to more than 70 percent. Simultaneously, the CO_2 release went from a high of about 80 million tons per year ... to about 13 million tons per year in 1987. Similar trends were cited for atmosphere release of dust, SO_2, and NO_x."

These results are more graphically illustrated in Figures 4 and 5. Note that the dust levels in Figure 5 were decreased from 75,000 tons to about 2,000 tons per year (Bauer and Fabre, 1989).

With respect to waste management, nuclear power is exceptionally clean in operation. Most of the concern is focused on the highly toxic and radioactive spent fuel and nuclear waste. What is unique about these, in addition to their toxicity and radioactivity, is that they are limited in volume, which facilitates waste disposal in contrast with the waste disposal problem for fossil-fueled plants. For example, a 1000 MWe coal plant with optimal pollution abatement equipment will

Figure 4. Releases of SO-2 (x1000 tons) and NO-x (x1000 tons NO-2) from EDF Power Plants

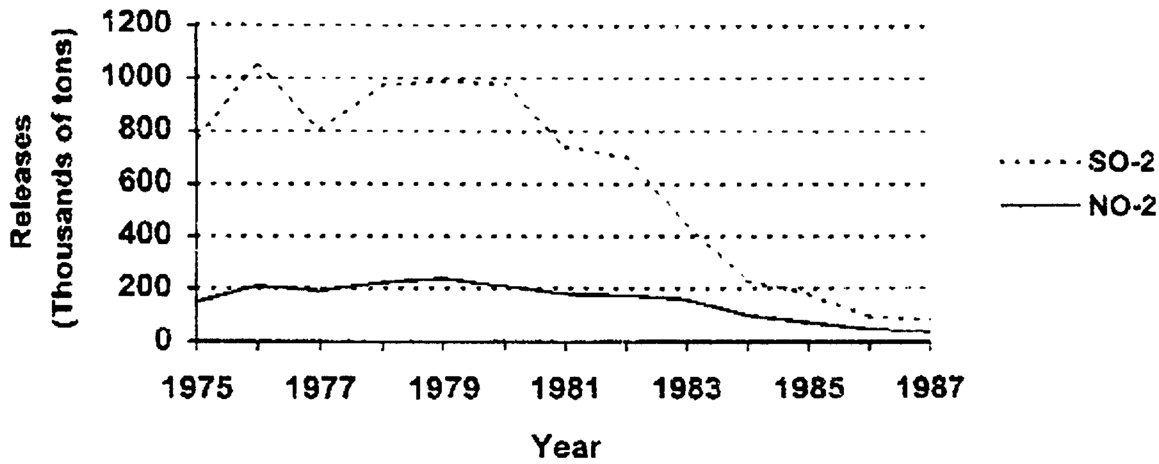
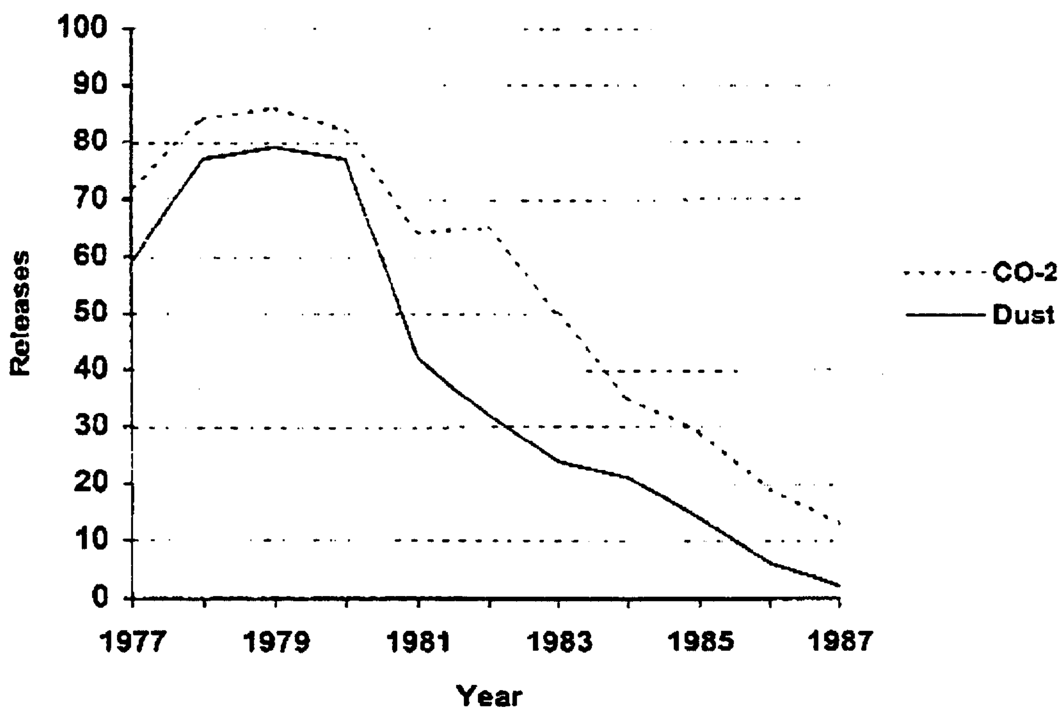


Figure 5. Releases of CO-2 (millions of tons) and Dust (thousands of tons) from EDF Power Plants



annually emit into the atmosphere:

- 900 metric tons of SO_2
- 4500 metric tons of NO_x
- 1300 metric tons of particulates
- 6,500,000 metric tons of CO_2

Depending on the quality of the coal, up to 1,000,000 metric tons of ashes containing hundreds of metric tons of toxic heavy metals (arsenic, cadmium, lead, mercury) will have to be disposed (Blix, 1997).

In contrast, a nuclear plant of 1000 MWe capacity produces **annually** some 35 metric tons of highly radioactive spent fuel. If the spent fuel is reprocessed, the volume of highly radioactive waste will be about 3 m^3 The entire nuclear chain supporting this 1000 MWe plant, from mining through operation, will generate, in addition, some 200 m^3 of intermediate level waste and some 500 m^3 of low level waste per year (Blix, 1997).

The question of safe disposal always comes up with respect to nuclear wastes that remain radioactive for tens of thousands of years. However, the argument that has been made that it is irresponsible to leave any long-lived radioactive waste behind us needs to be put into perspective. That argument applies with much greater strength to the toxic chemical residues, such as arsenic, mercury, lead, and cadmium that result from the burning of fossil fuels. The impact of these chemicals on health and safety is often more immediately drastic, and they do not have half-lives. They remain toxic forever. Additionally, the main problem with fossil fuel wastes is that they are so voluminous that there virtually is no place to dispose of them. Their final disposal sites are the earth and air we breathe. On the other hand, nuclear waste because of its relatively small volume can be stored safely and securely in a very limited space (Blix, 1997).

Thus in terms of solving Yoda's **Trilemma** of Economic Development, Resources, and Environment, nuclear power offers one solution.

To the scientist and engineer, nuclear power is an obvious choice, for the future, but let's now consider what more of the realities and risks are that dominate the business perspective.

The trend line on performance improvement since Three Mile Island in 1979 and the results achieved by the industry are, by any measure, remarkable. Nuclear Safety is orders of magnitude improved, when considering reduction in automatic scrams and core damage frequency in probabilistic risk assessment (PRA) calculations. Personnel safety and radiation exposure have experienced 70-80% improvement over the past 17 years. Volumes of solid radwaste generated have seen a 90% reduction. Finally, cost of production and plant run time, industry wide, are roughly 35% improved over the last 10 years.

But even as this is "some" good news, many more issues are not being adequately addressed and are the source of significant business risk. Let me suggest the substance of that risk in four areas:

NRC Regulatory Process
High Level Waste
Government Support
Public Support

NRC Regulatory Process

Unfortunately, the NRC process continues to be replete with unpredictability and an excess focus on compliance with insignificant licensing matters and paper work.

License Renewal activity will provide an opportunity for the NRC to demonstrate that it is changing its' ways – both BG&E with Calvert Cliffs and Duke with Oconee have filed applications. The question is "will the NRC carry-out its process in an efficient and predictable manner – will it be consistent, meet prior commitments to policy and process, and adhere to schedules?"

High Level Waste

No issue has been more frustrating than high level waste. The U.S. Government has intentionally created obstacles to the proper storage of high level waste and even low level waste. Utilities and state governmental bodies have filed lawsuits against DOE for their failure to meet specific contract requirements to begin taking waste on January 31, 1998. Even so, the administration is stonewalling any attempt to solve this problem. As a result U.S. customers could end up paying another $7 billion in the '98-'10 period for interim storage, when they have already paid $14 billion to the government into the high level waste fund —with most of that money was used for federal budget items having nothing to do with anything in the energy arena.

Government Support

As I discussed earlier, our government champions environmental attention to power generation, but refuses to recognize the benefits of nuclear power from this perspective. It is sometimes clear that the administration avoids even mentioning the word "nuclear".

Public Support

With a lack of government support and an adverse regulatory climate, the media and the public still have concerns about nuclear power. Moreover, there is still a considerable lack of basic understanding of this technology. This is evidenced in a study conducted by a large university which found that 43% of those surveyed believed that nuclear energy creates the greenhouse gases that are in part responsible for the "greenhouse effect".

Finally, consider what Senator Domenici said during a speech last October:

> "Strategic national issues just don't command a large audience. In no area has this been more evident during these last 25 years than in the critical and interrelated public policy questions involving energy, growth, and the role of nuclear technologies. As we leave the 20th century, arguably the American Century, and head for a new millenium, we truly need to confront these strategic issues with careful logic and sound science."
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> "Today, it is extraordinarily difficult to conduct a debate on nuclear issues. Usually, the only thing produced is nasty political fallout."
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> --Senator Pete Domenici (R-NM) speaking at Harvard University on October 31, 1997

Summary

With the world's population estimated to nearly double to 10 billion people by the year 2050 the economic activity and resources necessary to meet the fundamental needs and minimum requirements of that population is daunting. Previous attempts at industrializing the less developed or third world countries have resulted in detrimental environmental effects. They have led to the problems of the Green Revolution, massive deforestation, disputes over ownership of land and natural resources, exploitation of marine resources, impoverishment. and many other negative outcomes. All of these have exacerbated Yoda's **Trilemma.**

Thus, an alternative non-fossil source of energy is not only needed today, but will be imperative to fuel the increasing future energy demand while maintaining a quality environment. Other than renewable energy sources, the only other non-fossil energy source available today that has the potential to meet this future demand is nuclear power. It is **one** solution that mitigates the **Trilemma.**

But will the challenges facing nuclear be adequately addressed so as to present a more acceptable business risk in the new competitive market? Maybe and maybe not?

Nuclear power is a long-term technology. It could and should be a preferred technology from a safety and environmental perspective. While we continue to champion its advantages, we must continue to address the challenges it faces.

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